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FOR A

PLANARIZED PERPENDICULAR POLE TIP SYSTEM AND METHOD FOR MANUFACTURING THE SAME

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PLANARIZED PERPENDICULAR POLE TIP SYSTEM AND METHOD FOR MANUFACTURING THE SAME

FIELD OF THE INVENTION

The present invention relates to memory storage devices, and more particularly, this invention relates to improving the fabrication of magnetic head pole tip structures.

BACKGROUND OF THE INVENTION

Computer systems generally utilize auxiliary memory storage devices having media on which data can be written and from which data can be read for later use. A direct access storage device (disk drive) incorporating rotating magnetic disks is commonly used for storing data in magnetic form on the disk surfaces. Data is recorded on concentric, radially spaced tracks on the disk surfaces. Magnetic heads are then used to read data from the tracks on the disk surfaces.

FIG. **1** illustrates a prior art MR head, which may be employed as a magnetic head on a slider. The head **30B** has a pole tip region **49**, an insulation stack region and a coil region, the pole tip region **49** extending from the **ABS 47** to the insulation stack region, the insulation stack region extending from the pole tip region **49** to the back gap (not shown) and the coil region located in the insulation stack region but spaced from the pole tip region **49**. In the present framework, the first and second shield layers **S1** and **S2** are located in the pole tip region **49** for the protection of the MR sensor. The first shield

S1 terminates between the pole tip region **49** and the coil region along a slope **50**. This provides a sunken or depressed area **51** for subsequent thin film layers of the head which makeup the insulation stack. The second gap layer **G2** extends along the slope **50** of the first shield **S1**, thence perpendicular to the **ABS 47** toward a back region of the head. It should be noted that leads are not shown following the same path. The leads for the head **30B** may take a different path.

The layer **S2/P1**, write gap, insulation layer **I1**, write coil, insulation layers **I2** and **I3**, and the second pole piece **P2** are all recessed by the depression provided by the first shield layer **S1** in the insulation stack region lowering the height of the second pole piece **P2** above the write gap plane so as to enhance planarization of the second pole tip **PT2** **33**. This significantly increases the lithographic process window needed for the fabrication of the pole tip **PT2**. A thinner resist layer permits a narrower pole tip to be precisely constructed with good definition, thereby enhancing the bit density of the head.

The slope **50** of the first shield **S1** may be constructed by a resist layer with a negative slope. Permalloy may then be plated adjacent the negative slope, after which the resist is removed to produce the slope **50** of the first shield **S1**.

To further generalize the structure of the MR head, the ferromagnetic layers that are **S2/P1** may be separate layers. In addition, different layers in the head may be planarized [e.g. via chemical mechanical polishing or (CMP)] to increase a fabrication process window for the various parts of the head.

In the case where the write head was a perpendicular write head, one pole tip (e.g. **PT2 33**) would have a much smaller cross-section at the **ABS 47** plane compared to the other pole tip (e.g. **PT1 31**). The write gap **37** may also vary.

FIGs. **2A-2B** illustrate a method of manufacturing the pole tip structure associated with a magnetic head, such as that shown in FIG. **1**. See second pole piece **P2** of FIG. **1**, for example.

FIG. **2A** illustrates a cross-sectional view of an initial stack **200** with which a prior art pole tip structure may be manufactured. As shown, the stack **200** includes a first layer **202** which may include AlO_X or some other non-magnetic material. Deposited above the first layer **202** is a second layer **204** including, for example, NiFe or a material which substantially consists of a ferromagnetic material. A masking third layer **206** is deposited above the second layer **204**. The third layer **206** may include a masked photoresist which is used to define a pole tip structure as will soon become apparent.

FIG. **2B** illustrates another cross-sectional view of the stack **200** of FIG. **2** after various processes. In particular, the second layer **204** and a portion of the first layer **202** may be removed utilizing an ion milling process. As a result of the foregoing process, a pole tip structure **210** is defined with a pair of cavities flanking the same. Thereafter, additional AlO_X material **208** or similar material is used to fill the cavities.

It is often advantageous to have a pole tip structure **210** with beveled edges such as that shown in FIG. **2B**. It is also desirable to generate a pole tip structure that is rectangular with a low aspect ratio or similar height to width ratio as viewed at the cross-section at the **ABS 47** plane. Moreover, it is desirable that a top edge of the pole tip

structure **210** be planar in nature. Unfortunately, the top edge of the pole tip structure **210** may lose its planarity and exhibit a rounding effect (see **212** of FIG. **2B**) as a result of subsequent processes unless specific process steps are taken to maintain pole definition and function.

DISCLOSURE OF THE INVENTION

A method for manufacturing a pole tip structure for a magnetic head is provided. An etch stop layer is initially deposited after which a transfer layer is deposited. Further deposited is at least one masking layer. Reactive ion etching is then performed to define a trench in at least the transfer layer. A pole tip layer is then deposited in the trench to define a pole tip structure flanked at least in part by the transfer layer. A surface of the transfer layer or etch stop layer then remains in co-planar relationship with a surface of the pole tip structure.

In one embodiment, the etch stop layer may include an alumina material. Moreover, the etch stop layer may be deposited utilizing a sputtering operation. As an option, a chemical-mechanical planarization (CMP) operation may be performed on the etch stop layer.

In another embodiment, the transfer layer may include a silica material. Also, an adhesion layer may be deposited above the transfer layer. Optionally, the adhesion layer may include silicon.

In still another embodiment, a chemical mechanical polishing (CMP) stop layer may be positioned above the adhesion layer. Optionally, the CMP stop layer may include a diamond-like carbon material. As a further option, another transfer layer (i.e. silicon) may be deposited above the CMP stop layer.

As an option, the pole tip layer may include a CoFe material, a NiFe material, an alloy thereof, etc. Moreover, the pole tip layer may be deposited utilizing ion beam deposition, sputtering, etc.

In still another embodiment, an adhesion layer may be deposited above the pole tip layer. Such adhesion layer may optionally include silicon. Still yet, a chemical mechanical polishing (CMP) stop layer may be deposited above the adhesion layer, and a capping layer may be deposited above the CMP stop layer. Such CMP stop layer may include a diamond-like carbon material. A CMP operation may then be performed on the capping layer, such that it remains only over the pole tip structure after the CMP operation. A reactive ion etching operation may then be performed to remove the CMP stop layer surrounding the pole tip structure. Moreover, another CMP operation may subsequently be performed on a remaining portion of the pole tip layer surrounding the pole tip structure. A reactive ion etching operation may then be performed on a remaining portion of the CMP stop layer situated above the pole tip structure. A polishing operation may thus be performed on a remaining portion of the pole tip layer situated above the transfer layer.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and advantages of the present invention, as well as the preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings which are not necessarily drawn to scale.

FIGs. **1, 2A** and **2B** illustrate a pole tip structure system and method of manufacturing the same, in accordance with the prior art.

FIG. **3** is a perspective drawing of a magnetic recording disk drive system in accordance with one embodiment of the present invention.

FIG. **4** illustrates a process for manufacturing a pole tip structure for a magnetic head, in accordance with one embodiment.

FIG. **5A** illustrates a stack of various layers present after the initial operations of the method of FIG. **4**.

FIG. **5B** illustrates a stack of various layers present after the reactive ion etching operation of the method of FIG. **4**.

FIG. **5C** illustrates a stack of various layers present after the pole tip layer is deposited in accordance with the method of FIG. **4**.

FIGs. **5D** and **5E** each illustrate a stack of various layers present after the pole tip layer is planarized in accordance with the method of FIG. **4**.

FIG. **6A** illustrates a stack of various layers present after the pole tip layer is deposited in accordance with the method of FIG. **4**, in addition to some optional layers which may be deposited in accordance with an alternate embodiment.

FIG. **6B** illustrates a stack of various layers present after an optional chemical mechanical polishing (CMP) operation is performed on the stack shown in FIG. **6A**.

FIG. **6C** illustrates a stack of various layers present after a reactive ion etching operation is performed on the stack shown in FIG. **6B**.

FIG. **6D** illustrates a stack of various layers present after another CMP operation is performed on the stack shown in FIG. **6C**.

FIG. **6E** illustrates a stack of various layers present after another reactive ion etching operation is performed on the stack shown in FIG. **6D**.

FIG. **6F** illustrates a stack of various layers present after a polishing operation is performed on the stack shown in FIG. **6D**.

BEST MODE FOR CARRYING OUT THE INVENTION

The following description is the best embodiment presently contemplated for carrying out the present invention. This description is made for the purpose of illustrating the general principles of the present invention and is not meant to limit the inventive concepts claimed herein.

Referring now to FIG. **3**, there is shown a disk drive **300** embodying the present invention. As shown in FIG. **3**, at least one rotatable magnetic disk **312** is supported on a spindle **314** and rotated by a disk drive motor **318**. The magnetic recording media on each disk is in the form of an annular pattern of concentric data tracks (not shown) on disk **312**.

At least one slider **313** is positioned on the disk **312**, each slider **313** supporting one or more magnetic read/write heads **321**. More information regarding such heads **321** will be set forth hereinafter during reference to FIG. **4**. As the disks rotate, slider **313** is moved radially in and out over disk surface **322** so that heads **321** may access different portions of the disk where desired data are recorded. Each slider **313** is attached to an actuator arm **319** by way of a suspension **315**. The suspension **315** provides a slight spring force which biases slider **313** against the disk surface **322**. Each actuator arm **319** is attached to an actuator **327**. The actuator **327** as shown in FIG. **3** may be a voice coil motor (VCM). The VCM comprises a coil movable within a fixed magnetic field, the direction and speed of the coil movements being controlled by the motor current signals supplied by controller **329**.

During operation of the disk storage system, the rotation of disk **312** generates an air bearing between slider **313** and disk surface **322** which exerts a force on the slider. The air bearing thus counter-balances the slight spring force of suspension **315** and supports slider **313** off and slightly above the disk surface by a small, substantially constant spacing during normal operation.

The various components of the disk storage system are controlled in operation by control signals generated by control unit **329**, such as access control signals and internal clock signals. Typically, control unit **329** comprises logic control circuits, storage and a microprocessor. The control unit **329** generates control signals to control various system operations such as drive motor control signals on line **323** and head position and seek control signals on line **328**. The control signals on line **328** provide the desired current profiles to optimally move and position slider **313** to the desired data track on disk **312**. Read and write signals are communicated to and from read/write heads **321** by way of recording channel **325**.

The above description of a magnetic disk storage system, and the accompanying illustration of FIG. **3** are for representation purposes only. It should be apparent that disk storage systems may contain a large number of disks and actuators, and each actuator may support a number of sliders.

FIG. **4** illustrates a method **450** for manufacturing a pole tip structure for a magnetic head, in accordance with one embodiment. In one embodiment, the method of FIG. **4** may be used in the context of the head **321** of FIG. **3**. Of course, the method **450** may be implemented in any desired context.

In operation **452,** an etch stop layer is formed. As an option, the etch stop layer may include an alumina material, insulator-type material, or any other desired material capable of stopping a subsequent etching operation. Moreover, the etch stop layer may be deposited utilizing a sputtering operation or the like. This etch stop may also be planarized.

A planarization stop layer [i.e. chemical mechanical polishing (CMP) stop layer] may be deposited, in accordance with operation **460**. Such optional CMP stop layer may include a diamond-like carbon (DLC) material or any other type of CMP stop material (i.e. C, SiN_x, Ta, Ti, an alloy thereof, etc.). The CMP stop layer may also include adhesion layers. The adhesion layer material may be selected from the group consisting of Si, Ta, Cr, Ti, an alloy thereof, etc.

Next, in operation **462**, at least one photoresist layer (possibly multiple) is deposited above the CMP stop layer. In one embodiment, 0.2um of photoresist may be deposited. Of course, if the CMP layer and/or adhesion layer are optionally excluded, such photoresist layer may be deposited on the transfer layer. Thus, in the context of the present description, the term above may refer to any spaced (i.e. with another material therebetween) or contiguous relationship between layers.

In operation **464**, reactive ion etching may be used to create a trench in the CMP stop layer (if it exists), the adhesion layer (if it exists), and the transfer layer. Such reactive ion etching may further be performed such that not all of the photoresist is consumed. The remaining photoresist may be removed by any well known processes.

A pole tip layer may then be deposited in the trench to define a pole tip structure flanked at least in part by the transfer layer, as noted in operation **466**. In one embodiment, the pole tip structure may be constructed using NiFe, CoFe or any other desired suitable pole tip material. Moreover, the pole tip layer may be deposited utilizing ion beam deposition, sputtering, electroplating, etc. As an option, another adhesion layer may be deposited prior to the deposition of the pole tip layer material. Thereafter, in operation **468**, a chemical-mechanical planarization (CMP) operation is performed to remove excess portions of the pole tip layer.

Of course, any other desired operations may be subsequently applied. For example, the resultant pole tip structure may be encapsulated in an insulator (i.e. silica, alumina, etc.) to protect the pole tip structure, etc. for subsequent processing.

Thus, by the present method, there is no need for the fill-in procedure shown in Prior Art FIG. **2B** and, more importantly, there is less damage inflicted on the pole tip structure. This is manifested by a surface (i.e. upper and/or lower surface) of the transfer layer remaining in co-planar relationship with a surface (i.e. upper and/or lower surface, respectively) of the pole tip structure. More information regarding the present design will be set forth in greater detail during reference to FIGs. **5A-5D**. Moreover, various optional alternative embodiments will be set forth during reference to FIGs. **6A-6F**, and FIGs. **7-8.**

FIGs. **5A-5D** illustrate various exemplary structural embodiments that may result from the method **450** of FIG. **4**. While the following descriptions will be set forth in the

context of the various operations of the method **450** of FIG. **4**, it should be noted that the various operations and structural features may be implemented in any desired context.

FIG. **5A** illustrates a stack **500** of various layers present after initial operations **452-462** of the method **450** of FIG. **4**. As shown, an etch stop layer **502** is shown deposited with the transfer layer **504** and the CMP stop/adhesion layer **506** positioned thereon. Further deposited on such layers is a photoresist layer **508**. The present stack **500** is thus ready for the reactive ion etching of operation **464** of the method **450** of FIG. **4**.

FIG. **5B** illustrates a stack **500** of various layers present after the reactive ion etching operation **464** of the method **450** of FIG. **4**. As shown, the reactive ion etching creates a trench **510** through the transfer layer **504** and the etch stop/adhesion layer **506** (if it exists). Such trench **510** terminates at an upper surface of the etch stop layer **502.**

FIG. **5C** illustrates a stack **500** of various layers present after the pole tip layer is deposited in accordance with operation **466** of the method **450** of FIG. **4**. As shown, any remaining photoresist masking layer **508** may be removed, and the trench **510** filled with the pole tip layer material **522**. As mentioned earlier, another adhesion layer **524** may be deposited prior to the deposition of the pole tip layer material. As shown, a slight depression **525** exists above where the trench **510** resides.

In the event the masking layer **508** is not removed before pole tip deposition, the pole tip layer material **522** will subsequently cover the masking layer **508**. The masking layer **508** would be removed during a planarization process.

FIG. **5D** illustrates a stack **500** of various layers present after the pole tip layer is planarized in accordance with operation **468** of the method **450** of FIG. **4**. Again, there is no need for the fill-in procedure shown in Prior Art FIG. **2B** and, more importantly, there is less damage inflicted on the pole tip structure.

As shown in FIG. **5D**, the transfer layer **504** is in co-planar relationship with the pole tip structure and is discontinuous from the layers above (see CMP stop/adhesion layer **506**) and below (see etch stop layer **502**) the pole tip layer **522.** In other words, the transfer layer **504** has a height (i.e. thickness) substantially similar to that of the portion of the pole tip layer **522** defining the pole tip structure. Moreover, such transfer layer **504** is etchable.

To this end, a surface (i.e. an upper surface **547** and/or a lower surface **548**) of the transfer layer **504** remains in co-planar relationship with a surface (i.e. an upper surface **545** and/or a lower surface **546**), respectively, of the pole tip structure. Thus, the use of the transfer layer **504** (with optional overlying CMP stop layer) allows for greater control of the bevel angles of the resultant pole tip structure, since the material of such transfer layer **504** may be different from the underlying etch stop layer **502**. Moreover, the processing difficulties of image transfer milling into a pole tip material (i.e. NiFe, etc.) is avoided to create a trench **510** with a relatively low aspect ratio.

Similarly, if the transfer layer **504** is removed (e.g. via etching) and replaced with a fill material **580**, the pole tip layer **522** is not be adjacent to the transfer layer **504**. However, due to the planarization process, at least one of the surfaces of the pole tip layer **522** (i.e. coincident with the bottom surface of the pole tip **546**) is co-planar with a top

surface **558** of the etch stop layer **502**. The fill material **580** may or may not be similar to the etch stop layer **502**. This structure is shown in FIG. **5E**. It is also noteworthy to add that either a pole tip top surface **545** and/or bottom surface **546** may be flat, in one embodiment. This flatness may determine the shape of magnetic bits written along a track on the media.

FIG. **6A** illustrates a stack **600** of various layers present after the pole tip layer is deposited in accordance with operations **452-466** of the method **450** of FIG. **4**, in addition to some optional layers which may be deposited in accordance with an alternate embodiment. The purpose of an alternate method is to create a structure at the pole tip location that protrudes from the wafer plane. This protruding topography creates a structure that can be quickly planarized. Ideally, one wants to create a pole tip with a flat surface with an acceptable planarization process window. Such protruding structures are thus planarized quickly where planarizing flat portions of the wafer greatly reduces the removal rate or reduction of the thickness of the pole.

As shown, an etch stop layer **602** is shown deposited with the transfer layer **604** and the CMP stop/adhesion layer **606** positioned thereon, which have all been subject to the reactive ion etching of operation **464** of the method **450** of FIG. **4**. As shown, any remaining photoresist layer may be removed, and the trench filled with the pole tip layer material **622**.

Moreover, another CMP stop/adhesion layer **650** may be deposited on the pole tip layer **622**. Still yet, a capping layer **652** may be deposited on the CMP stop/adhesion

layer **650**. As will soon become apparent, such capping layer **652** may serve to protect the pole tip structure.

FIG. **6B** illustrates a stack **600** of various layers present after an optional CMP operation is performed on the stack **600** shown in FIG. **6A**. As shown, the portions of the capping layer **652** positioned over the area surrounding the pole tip structure are significantly removed, while a portion situated over the pole tip structure remains after the CMP operation.

FIG. **6C** illustrates a stack **600** of various layers present after a reactive ion etching operation is performed on the stack **600** shown in FIG. **6B**. As shown, such reactive ion etching operation may be performed to remove the CMP stop/adhesion layer **650** surrounding the pole tip structure. As shown, the capping layer **652** and CMP stop/adhesion layer **650** remain on an area over the pole tip structure (i.e. in the slight depression).

FIG. **6D** illustrates a stack **600** of various layers present after another CMP operation is performed on the stack **600** shown in FIG. **6C**. As shown, the remaining portion of the pole tip layer **622** surrounding the pole tip structure is removed, leaving the mound of the pole tip layer **622** with a portion of the CMP stop/adhesion layer **650** thereon.

FIG. **6E** illustrates a stack **600** of various layers present after another reactive ion etching operation is performed on the stack **600** shown in FIG. **6D**. As shown, the reactive ion etching operation may be performed on a remaining portion of the CMP stop/adhesion layer **650** situated above the pole tip structure.

FIG. **6F** illustrates a stack **600** of various layers present after a polishing operation is performed on the stack **600** shown in FIG. **6D**. As shown, the polishing operation may be performed on a remaining portion of the pole tip layer situated above the transfer layer. Again, a surface (i.e. an upper surface and/or a lower surface) of the transfer layer remains in co-planar relationship with a surface (i.e. an upper surface and/or a lower surface), respectively, of the pole tip structure.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.